MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2022/2023 (TERM ID 2210)

EEL1196 – INSTRUMENTATION & MEASUREMENT TECHNIQUES

(All Sections / Groups)

9 FEBRUARY 2023
2:30 P.M – 4:30 P.M.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of 10 pages including cover page with 4 Questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. List of formulas are provided on page 7-10.
4. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Distinguish between sensor and transducer as the element of a measurement system. Give an example of a component that is classified as a sensor.

[3 marks]

(b) The resistance of a potentiometer is set to be 4.95 kΩ. During an experiment, the resistance is measured using three multimeters, and 4 readings were taken for each multimeter. The readings were recorded as follows:

Multimeter A: 4.94 kΩ, 4.95 kΩ, 4.96 kΩ, 4.95 kΩ
Multimeter B: 4.96 kΩ, 4.92 kΩ, 4.98 kΩ, 4.90 kΩ
Multimeter C: 4.91 kΩ, 4.92 kΩ, 4.92 kΩ, 4.91 kΩ

(i) Which multimeter has the highest accuracy? Justify your answer.

[2 marks]

(ii) Which multimeter has high precision but low accuracy? Justify your answer.

[2 marks]

(iii) Which multimeter has low accuracy and low precision? Justify your answer.

[2 marks]

(c) A voltmeter has a uniform scale with the full-scale reading of 300V. If the scale has 100 divisions, and 1/5 of a scale division can be estimated with certainty, what is the resolution of the voltmeter in volts?

[2 marks]

(d) **Figure Q1(d)** shows a circuit consisting of resistors and a DC voltage source. It is given that:

$R_1 = 10\text{k}\Omega \pm 5\%$, $R_2 = 5\text{k}\Omega \pm 3\%$, $R_3 = 1\text{k}\Omega \pm 5\%$, and $I_1 = 0.5\ mA \pm 7\%$.

(i) Calculate the total resistance, R_T and its % relative limiting error

[10 marks]

(ii) Calculate the voltage drop across R_1 and its % relative limiting error.

[4 marks]

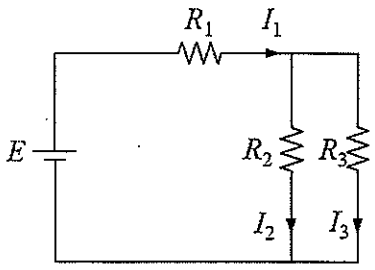

Figure Q1(d)

Continued...

Question 2

(a) Describe the function of damping torque in an indicating instrument. State 2 methods to produce damping torque.

[4 marks]

(b) A permanent magnet moving coil (PMMC) instrument gives a full-scale deflection when carrying a current of 200 mA. The internal resistance is 50 Ω. Draw a circuit to extend the range of the instrument to be able to measure up to 4 A. Hence, determine the shunt resistance value to be included in the circuit.

[5 marks]

(c) A dynamometer type ammeter gives a deflection of 60° when the current flow through the fixed coil is 0.2 A and the current flow through the moving coil is 1.5mA. Determine the spring constant (Nm/degree) used for the control torque.

[4 marks]

(d) State TWO (2) differences between a ballistic galvanometer and a fluxmeter.

[4 marks]

(e) A bar sample is pulled out from a 20 turns coil that is connected to a ballistic galvanometer. The galvanometer constant is 110 μC/div and the total resistance of the circuit is 15Ω. The meter gives a deflection of 6 divisions when the bar is pulled. Determine:

i) magnetic flux density in the bar if the cross-sectional area is 3 cm^2

[5 marks]

ii) the number of turns required to cause the deflections of 7 divisions when the same bar sample is pulled from the same circuit.

[3 marks]

Continued...

Question 3

(a) A Wheatstone bridge connected to a DC source of 5 V is shown in **Figure Q3(a).** The values of the resistors are given as $R_1 = 3\text{k}\Omega$, $R_2 = 120\Omega$, $R_3 = 1\text{k}\Omega$, and $R_4 = 10\text{k}\Omega$. Find the offset voltage, V_{ab}.

[3 Marks]

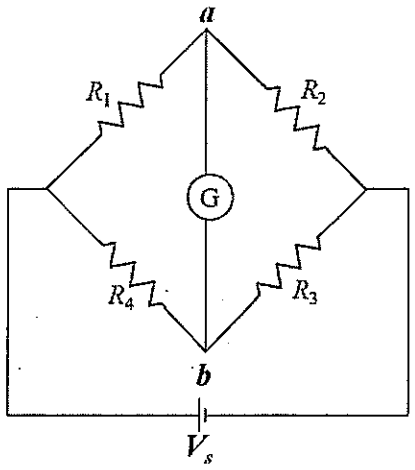

Figure Q3(a)

(b) **Figure Q3(b)** is a parallel resistance capacitance bridge connected to an AC source operating at 200Hz.

(i) Derive the equations for R_x and C_x. [7 marks]

(ii) Find the values of R_x, C_x and the D factor of the bridge, given that it is balanced when $R_1 = 220\Omega$, $R_3 = 3\text{k}\Omega$, $R_4 = 23\text{k}\Omega$ and $C_3 = 0.9\ \mu\text{F}$.

[6 marks]

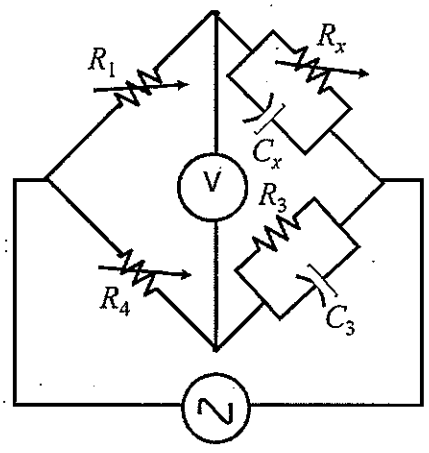

Figure Q3(b)

Continued...

(c) The **Figure Q3(c)** shows an AC Maxwell Wien Bridge. The bridge is balanced when the resistances $R_1 = 520\ \Omega$, $R_2 = 4\ \text{k}\Omega$ and $R_4 = 130\ \Omega$. The capacitance $C_1 = 0.35\ \mu\text{F}$. Derive the equations for L_x and R_x and find their respective values.

[9 marks]

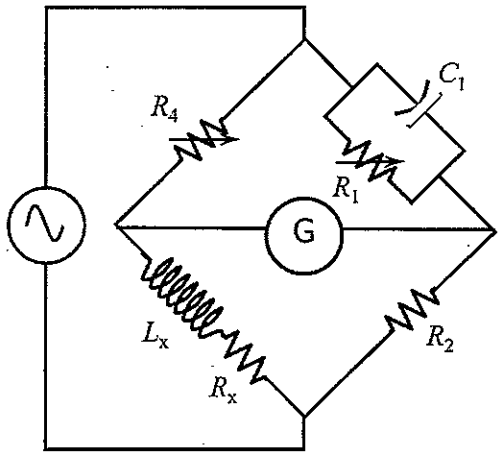

Figure Q3(c)

Continued...

Question 4

(a) A balanced 3-phase, 100 Hz supply with 300 V between lines is connected to a balanced star-connected load. Each phase of the load is made of a coil with a resistance of 30 Ω and an inductance of 70 mH. Determine:

(i) the line current [5 marks]

(ii) the power factor [2 marks]

(iii) the total power absorbed by the load. [2 marks]

(iv) the readings of each wattmeters if the two wattmeter method is used to measure the total power. [4 marks]

(b) Describe the working principle of a strain gauge. [3 marks]

(i) The resistance of a strain gauge with a gauge factor of 5 changes from 5 kΩ to 5.8 kΩ. Calculate the strain applied.

[3 marks]

(ii) If the initial length of the gauge is 0.7 cm, what is the final length after the strain in part (i) is applied?

[3 marks]

(c) A An LVDT is used to measure the displacement of an object. The maximum range is ± 5 *cm*. The sensitivity is 1.2 V/cm and the input voltage 7.5 V.

(i) Determine the output voltage when the core is at the positive maximum position. [2 marks]

(ii) Determine the displacement in cm if the output voltage is 4.1 V.

[1 mark]

Continued...

LIST OF FORMULAS

General concepts of Measurements

Sum and difference of quantities:

$y = \pm x_1 \pm x_2 \pm \cdots \pm x_n; \delta y = \pm(\delta x_1 + \delta x_2 + \cdots + \delta x_n)$

Product of quantities: $y = x_1 x_2 \ldots x_n; \quad \frac{\delta y}{y} = \pm \sum_{i=1}^{n} \frac{\delta x_i}{x_i}$

Quotient of quantities: $y = \frac{1}{x_1 x_2 \ldots x_n}; \quad \frac{\delta y}{y} = \pm \sum_{i=1}^{n} \frac{\delta x_i}{x_i}$

Power of a factor: $y = {x_1}^{m_1} {x_2}^{m_2} \ldots {x_n}^{m_n}; \ \frac{\delta y}{y} = \pm \sum_{i=1}^{n} m_i \frac{\delta x_i}{x_i}$

Indicating instrument

Spring control: $T_c \propto \theta$

Gravity control: $T_c \propto \sin\theta$

Moving Iron Instrument: $T_d = \frac{1}{2} I^2 \frac{dL}{d\theta}$

PMMC: $T_d = BINA$

Dynamometer: $T_d = NKI_1 I_2 A = I_1 I_2 \frac{dM}{d\theta}$

Power & Energy Measurement

Active power, $P = VI \cos\phi$

Reactive power, $Q = VI \sin\phi$

Apparent power, $S = VI$

Power factor: $\cos\phi$

$\varphi = \tan^{-1}\left(\frac{X_L}{R}\right)$

Wattmeter: $T_{d(average)} = k_d V_L I_L \cos\varphi, \quad k_d = \frac{k_1}{R_p}, \quad R_p = R_M + R_S$

Power loss for connection moving coil after fixed coil: $P_M = \frac{{V_L}^2}{R_P}$

Power loss for connection moving coil before fixed coil: $P_C = {I_L}^2 R_C$

Continued...

3-phase voltage and current relationship:

For star (Y) connected load	For mesh (Δ) connected load
$V_L = \sqrt{3}V_P$	$V_L = V_P$
$I_L = I_P$	$I_L = \sqrt{3}I_P$

3-phase system total load power, $P_T = \sqrt{3}V_L I_L \cos\varphi$

One wattmeter method: $P_T = 3 \times P_1$

Three wattmeters method: $P_T = P_1 + P_2 + P_3$

Two wattmeters method: $P_T = P_1 + P_2; \quad P_1 = V_L I_L \cos(\varphi + 30°);$

$$P_2 = V_L I_L \cos(\varphi - 30°)$$

$\tan\varphi = \frac{\sqrt{3}(P_2 - P_1)}{P_1 + P_2}$; $\cos\varphi = \frac{1}{\sqrt{1+3\left[\frac{P_2-P_1}{P_1+P_2}\right]^2}}$

Error due to moving coil inductance: $T_{d(average)} = k_d V_L I_L \cos\beta \cos(\varphi - \beta);$

Correction factor: $\frac{True\ power}{Metered\ power} = \frac{\cos\varphi}{\cos\beta\cos(\varphi-\beta)}$; where $\cos\beta = \frac{R_P}{|Z_M|}$

Measurement of R, L and C

$R = \frac{\rho L}{A}$

Capacitors equivalent circuit:

Series RC: $Z_s = R_s + \frac{1}{j\omega C_s}$, $D = \omega C_s R_s$

Parallel RC: $Y_p = \frac{1}{R_p} + j\omega C_p$, $D = \frac{1}{\omega C_p R_p}$

Inductors equivalent circuit:

Series RL: $Z_s = R_s + j\omega L_s$, $Q = \frac{\omega L_s}{R_s}$

Parallel RL: $Y_p = \frac{1}{R_p} + \frac{1}{j\omega L_p}$, $Q = \frac{R_p}{\omega L_p}$

Continued...

Magnetic Measurement

Ballistic galvanometer: $Q = \frac{I_s}{\omega_s \theta_s}\left(1 + \frac{\lambda}{2}\right)\theta_1$

$$Q = K\theta_1$$

Magnetic bar testing: $\theta_1 = \frac{Q}{K} = \frac{N\phi}{KR}$

Fluxmeter: $K_1 \Delta\theta \approx N\Delta\phi$

Fluxmeter with shunt: $K_1 \Delta\theta \approx \frac{R_s}{R_s + R_c} N\Delta\phi$

Ring sample testing: $\theta_1 = \frac{Q}{K} = \frac{2N_2\phi}{KR}$

$$H = \frac{N_1 I}{l}$$

$$\mu_s = \frac{B}{H} = \frac{l}{A_s N_1 I}\phi$$

Bar and Yoke or Hopkinson Method: $R_s = \frac{l}{\mu_s A_s}$

$$\phi = \frac{NI}{R_y + R_j + R_s}$$

$$\mu_s = \frac{l}{A_s NI}\phi$$

Magnetization curves by fluxmeter: $B = \frac{C\theta}{2N_2 A}$

Wattmeter method: $B'_m = \frac{E}{4K_f A_s f N_2}$

$$B_m = B'_m - \mu_0 H_m \left(\frac{A_c}{A_s} - 1\right)$$

$$P_i = P\frac{E}{V} - \frac{E^2}{r_p + r_c} = P\left(1 + \frac{r_c}{r_p}\right) - \frac{E^2}{r_p + r_c}$$

Continued…

Measurement of Non-electrical Quantities

Potentiometer: $V_0 = \left(\frac{V_T}{X_T}\right) x_0$

Strain gauge: $G = \frac{\Delta l}{l}$

$K = \frac{\left(\frac{\Delta R}{R}\right)}{G}$

Capacitance: $C = \frac{KA\varepsilon_0}{d}$

Piezoelectric transducer: $V_0 = kPt$

Pressure at the bottom of a tank: $p = \rho gh$

Resistance temperature detector (RTD): $R_t = R_0(1 + \alpha_0 \Delta t)$

Self-heating in RTD: $\Delta T = \frac{P}{P_D}$

Thermocouple: $E = c(T_1 - T_2) + k(T_1^2 - T_2^2)$

End of Paper